

# Planetary Pressure Wave of 4- to 5-Day Period in the Tropics

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**ABSTRACT**—Surface pressure data during the International Geophysical Year period for 76 stations in the tropical zone 20°N–20°S have been examined to investigate the propagation characteristics, if any, of the 4- to 5-day pressure oscillations. Cross-spectrum analysis with a first-difference filter and the Tukey window has been

employed. The phase spectrum shows that the 4- to 5-day oscillations result from a westward moving wave having a periodicity of 4–5 days and wave number 1. The direction of propagation is identical in both hemispheres and shows no inclination to latitude circles.

## 1. INTRODUCTION

In a recent paper, Misra (1971) presented evidence for the global scale of an atmospheric pressure oscillation of 4- to 5-day periodicity. A plot of the phase difference against the longitude difference for stations arranged in zonal belts demonstrates the existence of a westward propagating wave having periodicity of 4–5 days and wave number 1. The wave was earlier evidenced in an analysis by Wallace and Chang (1969), who used data for a few stations north of the Equator. The present paper examines more closely the behavior of this wave propagation in the tropical zone 20°N–20°S.

## 2. DATA AND COMPUTATION

The data for the study cover the tropical stations from the global analysis undertaken by Misra (1971). The identifications of 76 stations chosen in the Tropics are given in table 1. The data consist of 549 daily 1200 GMT values of sea-level pressure for the International Geophysical Year period (July 1, 1957–Dec. 31, 1958). Low-level stations have been selected to minimize the error due to pressure reduction.

As in Misra (1971), the computation of spectra in the present work follows the method of Jenkins and Watts (1968), with the divisor  $N$  (the total number of data points) being used in the covariance estimation instead of  $N-L$  ( $L$ =lag used). A first-difference filter has also been utilized to cut down the low-frequency characteristics of the series. Thus, the final analysis covers the daily 24-hr pressure-tendency values for the stations.

To study the propagation characteristics, we grouped the stations in 5° zonal belts. For the consideration of phase, the bivariate spectral methods have been extended to this multivariate case. A test, referred to and cited by Misra (1971), shows preference for the use of lag 20 with the Tukey window (Jenkins and Watts 1968) for smoothing purposes.

As the first step, the phases at all frequencies for different stations are calculated with respect to a particular reference station. From the various frequencies obtained with lag 20, attention is drawn to the particular periodicity of 4.4 days. This choice comes from a study of the auto-spectra of the stations, which invariably show a peak in the region of 4–5 days. This fact is discussed in detail by Misra (1971). The phase estimates of the stations, obtained for the 4.4-day period wave, are then plotted against their longitude differences from the reference station. The latter is taken positive eastward.

The reference station is then changed and the process is repeated with the new plot overlaid on the previous one. After using all the stations in a particular belt as references, the computations are carried on to the next belt.

## 3. RESULTS

The plots of phase difference against longitude difference for various reference stations in different zonal belts in two hemispheres are presented in figures 1 and 2. The figures show that there is a tendency for the phase difference to attain the value  $2\pi$  while a complete circle around the globe is covered. The behavior is unchanged with the change of reference stations and hence can be ascribed to a property of the whole belt. It may be mentioned that the coherency for the 4.4-day wave with various stations taken as references varies between 0.2 and 0.7. If one takes an average of 0.5 with the number of degrees of freedom being as high as 73, the 95-percent confidence interval for the phase estimates is approximately  $\pm 20^\circ$ . Thus, with all statistical reliability, the 4- to 5-day oscillation in surface pressure results in a westward propagating wave having the same periodicity and its wavelength equaling the circumference of a zonal circle. A comparison between different belts in two hemispheres does not show any specific change. The propagation properties are seen to be practically identical on both sides of the Equator.

TABLE 1.—Station identification

| Station name          | Latitude | Longitude | Height (m) |
|-----------------------|----------|-----------|------------|
| <b>0°–5° N</b>        |          |           |            |
| Libreville            | 0°27'N   | 9°25'E    | 10         |
| Mogadiscio            | 2°02'N   | 45°21'E   | 9          |
| Singapore             | 1°21'N   | 103°54'E  | 10         |
| Tarawa                | 1°21'N   | 172°55'E  | 4          |
| Fanning Island        | 3°54'N   | 159°23'W  | 5          |
| Santa Elena           | 4°36'N   | 61°07'W   | 907        |
| Tabou                 | 4°25'N   | 7°22'W    | 10         |
| <b>5°–10° N</b>       |          |           |            |
| Makurdi               | 7°41'N   | 8°37'E    | 97         |
| Galcayo               | 6°51'N   | 47°16'E   | 302        |
| Trivandrum            | 8°29'N   | 76°57'E   | 64         |
| Songkhla              | 7°11'N   | 100°37'E  | 10         |
| Davao                 | 7°04'N   | 125°36'E  | 20         |
| Truko                 | 7°28'N   | 151°51'E  | 8          |
| Majuro                | 7°05'N   | 171°23'E  | 3          |
| Albrook               | 8°58'N   | 79°36'W   | 9          |
| Atkinson              | 6°30'N   | 58°15'W   | 28         |
| Bonthe                | 7°32'N   | 12°30'W   | 8          |
| <b>10°–15° N</b>      |          |           |            |
| Potiskum              | 11°42'N  | 11°02'E   | 414        |
| Assab                 | 13°01'N  | 42°43'E   | 14         |
| Madras                | 13°00'N  | 80°11'E   | 16         |
| Bangkok               | 13°44'N  | 100°30'E  | 12         |
| Daet                  | 14°07'N  | 122°57'E  | 11         |
| Anderson              | 13°34'N  | 144°55'E  | 162        |
| Eniwetok              | 11°21'N  | 162°21'E  | 6          |
| Seawell Airport       | 13°04'N  | 59°29'W   | 56         |
| Ziguinchor            | 12°33'N  | 16°16'W   | 23         |
| <b>15°–20° N</b>      |          |           |            |
| Bilma                 | 18°41'N  | 12°55'E   | 357        |
| Port Sudan            | 19°35'N  | 37°13'E   | 2          |
| Bombay                | 19°07'N  | 72°51'E   | 4          |
| Phitsanulok           | 16°50'N  | 100°16'E  | 50         |
| Laoag                 | 18°11'N  | 120°32'E  | 5          |
| Wake Island           | 19°17'N  | 166°39'E  | 4          |
| Johnston Island       | 16°44'N  | 169°31'W  | 5          |
| Hilo                  | 19°43'N  | 155°04'W  | 11         |
| Manzanillo, Mexico    | 19°03'N  | 104°20'W  | 6          |
| Swan Island           | 17°24'N  | 83°56'W   | 11         |
| Raizet                | 16°16'N  | 61°31'W   | 8          |
| Mindelo               | 16°53'N  | 24°59'W   | 15         |
| <b>0°–5° S</b>        |          |           |            |
| Mayumba               | 3°25'S   | 10°39'E   | 34         |
| Mombasa               | 4°02'S   | 39°37'E   | 56         |
| Mahé                  | 4°37'S   | 55°27'E   | 1          |
| Bengkulu              | 3°52'S   | 102°20'E  | 16         |
| Ambon                 | 3°42'S   | 128°05'E  | 12         |
| Kalmana               | 3°40'S   | 133°45'E  | 3          |
| Rabaul                | 4°13'S   | 152°11'E  | 8          |
| Canton Island         | 2°46'S   | 171°43'W  | 3          |
| Iquitos               | 3°45'S   | 73°15'W   | 126        |
| Belém                 | 1°26'S   | 48°29'W   | 24         |
| <b>5°–10° S</b>       |          |           |            |
| Luanda                | 8°51'S   | 13°14'E   | 70         |
| Dar es Saalam         | 6°53'S   | 39°12'E   | 58         |
| Diego Garcia          | 7°21'S   | 72°29'E   | 2          |
| Djakarta              | 6°11'S   | 106°50'E  | 8          |
| Saumlaki              | 7°59'S   | 131°18'E  | 24         |
| Nukunono              | 9°12'S   | 171°55'W  | 3          |
| Taiohae               | 8°56'S   | 140°05'W  | 18         |
| Chiclayo              | 6°47'S   | 79°50'W   | 37         |
| Conceicao do Araguaia | 8°16'S   | 49°17'W   | 157        |
| Ascension Island      | 7°55'S   | 14°25'W   | 6          |
| <b>10°–15° S</b>      |          |           |            |
| Lobito                | 12°22'S  | 13°22'E   | 3          |
| Agalega               | 10°33'S  | 56°45'E   | 8          |
| Christmas Island      | 10°25'S  | 105°40'E  | 17         |
| Darwin Aerodrome      | 12°26'S  | 130°52'E  | 6          |
| Vanikoro              | 11°49'S  | 166°47'E  | 2          |
| Pukapuka              | 10°53'S  | 165°49'W  | 3          |
| Takaroa               | 14°29'S  | 145°05'W  | 3          |
| Pisco                 | 13°45'S  | 76°17'W   | 7          |
| Salvador              | 12°54'S  | 38°20'W   | 13         |

TABLE 1.—Concluded

| Station name      | Latitude | Longitude | Height (m) |
|-------------------|----------|-----------|------------|
| <b>15°–20° S</b>  |          |           |            |
| Mocamedes         | 15°12'S  | 12°09'E   | 45         |
| Mainitirano       | 18°03'S  | 44°02'E   | 25         |
| Rodrigues Island  | 19°41'S  | 63°25'E   | 59         |
| Broome            | 17°57'S  | 122°13'E  | 9          |
| Vila              | 17°45'S  | 168°19'E  | 20         |
| Niue              | 19°02'S  | 169°55'W  | 6          |
| Hikueru           | 17°33'S  | 142°40'W  | 3          |
| Arica             | 18°22'S  | 70°21'W   | 35         |
| St. Helena Island | 15°58'S  | 5°42'W    | 6          |

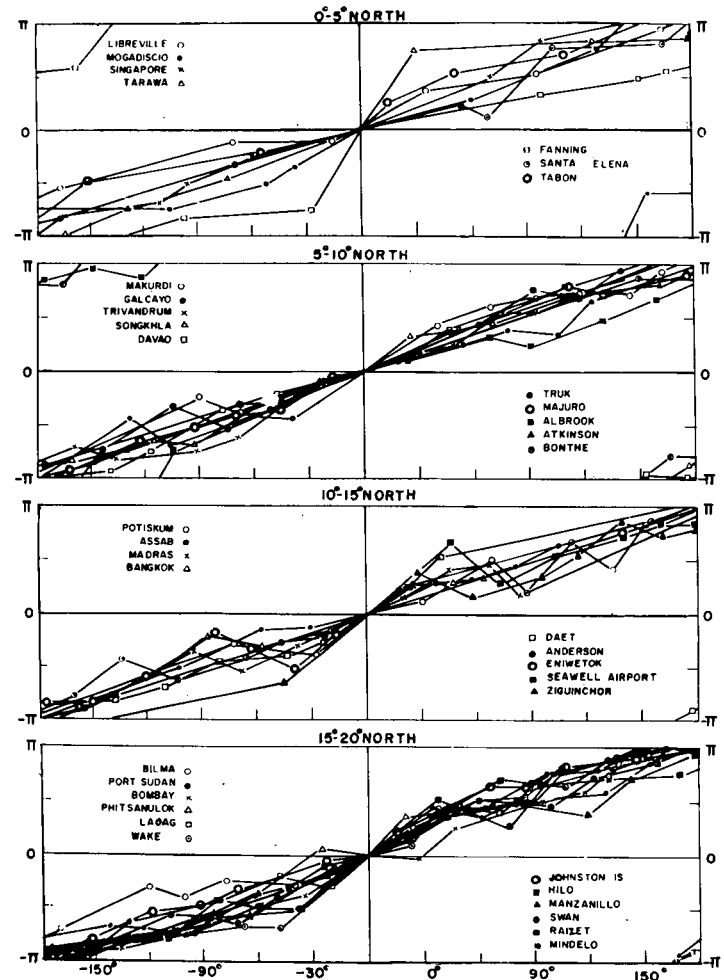


FIGURE 1.—Plot of phase difference against longitude difference for zonal belts in the Northern Hemisphere (plotted for the wave of periodicity 4.4 days). Different markings of points denote the phases of different stations in the belt with respect to a particular station as indicated.

The stations are then grouped in different meridian belts aligned along previously chosen meridians. Comparison of phases for stations arranged on four meridians separated by 90° (i.e., 10°E, 100°E, 170°W, 80°W) is given in table 2. The reference station has been chosen

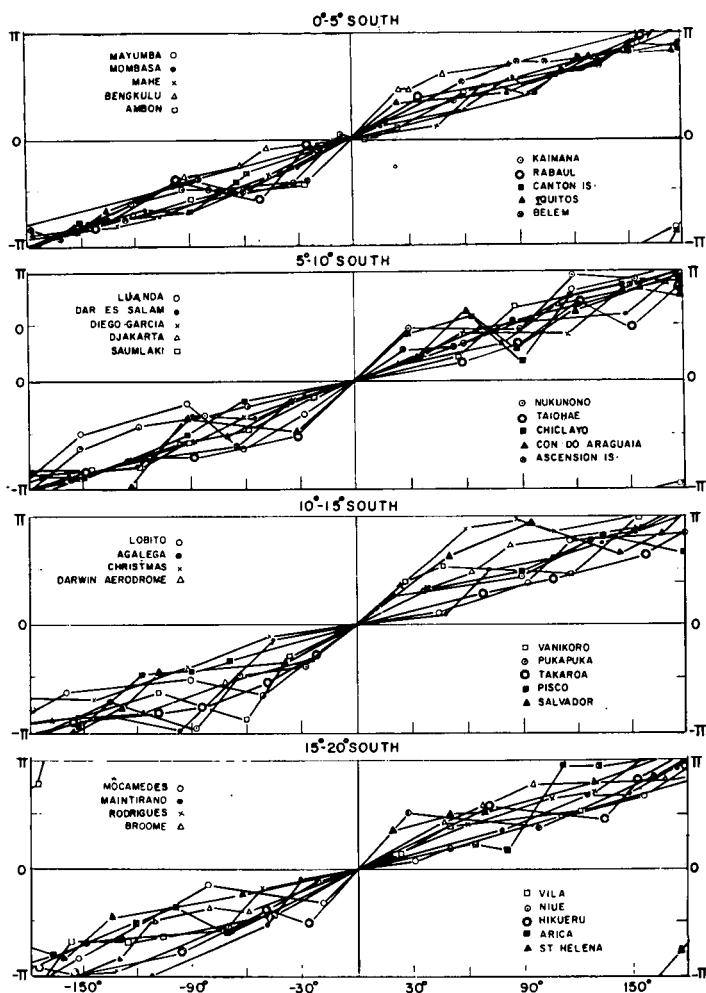


FIGURE 2.—The same as figure 1 for stations in the Southern Hemisphere.

as the one that is closest to the meridian considered for the group. As is seen from the table, the phase differences of stations along the same meridian are quite small and all the values lie within the 95-percent confidence interval. This provides strong evidence that the wave reaches a particular meridian in all zonal belts in practically the same epoch. The propagation, therefore, is purely zonal.

#### 4. DISCUSSION

The study gives conclusive evidence for a 4- to 5-day planetary pressure wave in the Tropics. The speed of the wave matches those obtained in some earlier studies on planetary waves by Deland (1964), Eliassen and Machenhauer (1965), and others. With a plot of the amplitude and phase of the Fourier zonal harmonics of the 500-mb height for the latitudes 40°, 50°, and 60°N, Deland (1964) showed that the dominant retrogressive wave speed was 90° of longitude per day for the wave of wave number 1. For the same large-scale wave, Eliassen and Machenhauer (1965) found evidence of westward propagation with a

TABLE 2.—Comparison of phase differences for stations arranged on meridian lines

| Station name                            | Latitude | Longitude difference | Phase difference | Coherence |
|---|----------|----------------------|------------------|-----------|
| <b>10° East meridian</b>                |          |                      |                  |           |
| Reference—Mayumba 3°25'S, 10°39'E       |          |                      |                  |           |
| Mocâmedes                               | 15°12'S  | 1°30'                | 16°              | 0.27      |
| Lobito                                  | 12°22'S  | 2°43'                | 10°              | .31       |
| Luanda                                  | 8°51'S   | 2°35'                | 1°               | .45       |
| Libreville                              | 0°27'N   | —1°14'               | —12°             | .56       |
| Makurdi                                 | 7°41'N   | —2°02'               | —9°              | .33       |
| Potiskum                                | 1°42'N   | 0°23'                | —13°             | .13       |
| Bilma                                   | 18°41'N  | 2°16'                | 10°              | .41       |
| <b>100° East meridian</b>               |          |                      |                  |           |
| Reference—Phitsanulok 16°50'N, 100°16'E |          |                      |                  |           |
| Christmas Island                        | 10°25'S  | 5°24'                | —32°             | 0.20      |
| Djakarta                                | 6°11'S   | 6°34'                | 2°               | .32       |
| Bengkulu                                | 3°25'S   | 2°04'                | —21°             | .17       |
| Singapore                               | 1°21'N   | 3°38'                | —13°             | .42       |
| Songkhla                                | 7°11'N   | 0°21'                | —16°             | .48       |
| Bangkok                                 | 13°44'N  | 0°14'                | —8°              | .66       |
| <b>170° West meridian</b>               |          |                      |                  |           |
| Reference—Niue 19°2'S, 169°55'W         |          |                      |                  |           |
| Pukapuka                                | 10°53'S  | 0°06'                | 21°              | 0.27      |
| Nukunono                                | 9°12'S   | —2°00'               | —13°             | .24       |
| Canton Island                           | 2°46'S   | —1°48'               | 20°              | .19       |
| Johnston Island                         | 16°44'N  | 0°24'                | —6°              | .23       |
| <b>80° West meridian</b>                |          |                      |                  |           |
| Reference—Chiclayo 6°47'S, 79°50'W      |          |                      |                  |           |
| Arica                                   | 18°22'S  | 9°29'                | 9°               | 0.23      |
| Pisco                                   | 13°45'S  | 3°33'                | 6°               | .44       |
| Iquitos                                 | 3°45'S   | 6°35'                | 34°              | .22       |
| Albrook                                 | 8°58'N   | 0°14'                | 21°              | .35       |
| Swan Island                             | 17°24'N  | —4°06'               | 16°              | .33       |

speed of 70° of longitude per day in the 24-hr tendency field of 500-mb heights. These studies confirmed the earlier model of Haurwitz (1940). Deland and Lin (1967) have tried to predict the speed of the traveling planetary scale waves from the tendency field using the barotropic vorticity equation, but no apparent improvement over the simple Rossby-Haurwitz model has yet been accomplished.

A discussion of the vertical propagation of the planetary waves is given by Lindzen (1967). It is found that as one gets sufficiently near the Equator, waves of any period and zonal wave number will become "untrapped," contrary to the analysis of Charney and Drazin (1961), and propagate upward as internal gravity waves. The upward propagation of the waves evidenced in the paper is yet to be observed. Work in this regard with a view to the dynamics of these waves will be reported in a forthcoming paper.

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